Clinical Neurophysiology 110 (1999) 272–279

The effects of a 20 min nap in the mid-afternoon on mood, performance and EEG activity

Mitsuo Hayashi*, Makiko Watanabe, Tadao Hori

Department of Behavioral Sciences, Faculty of Integrated Arts and Sciences, Hiroshima University, Higashi-hiroshima, Japan

Accepted for publication: 24 July 1998

Abstract

Objective: The aim of the study is to examine the effects of a 20 min nap in the mid-afternoon on mood, performance and EEG activities.

Methods: Seven young adults who had normal sleep–wake habits without habitual daytime napping participated in the study. They underwent Nap and No-nap conditions at intervals of 1 week. After a nocturnal sleep recording (00:00–08:00 h), their EEG recordings during relaxed wakefulness, and their mood, performance and self-ratings of performance level were measured every 20 min from 10:00 to 18:00 h. For the nap condition, they went to bed at 14:00 h and were awakened when 20 min had elapsed from the onset of sleep stage 1. For the No-nap condition, they took a rest without sleep by sitting on a semi-reclining chair.

Results: All of the subjects were awakened from sleep stage 2 during the nap. The 20 min nap improved the subjective sleepiness, performance level and self-confidence of their task performance. The nap also suppressed EEG alpha activity during eyes-open wakefulness.

Conclusions: The results suggest that a short 20 min nap in the mid-afternoon had positive effects upon the maintenance of the daytime vigilance level.

Keywords: Nap; Post-lunch dip; Daytime sleepiness; Performance; Vigilance; EEG alpha activity

1. Introduction

It is well-known that the performance of humans declines in the afternoon (the so-called ‘post-lunch dip’) (Blake, 1967). Daytime sleepiness and nodding off also occur at approximately 14:00–16:00 h (Dinges, 1989, 1992). Fatigue-related accidents often occur at this time (Mitler et al., 1988). Studies examining polyphasic sleep opportunities have shown that sleep tendencies are enhanced during this period (Richardson et al., 1982; Lavie, 1986; Carskadon, 1989). The post-lunch sleepiness occurs whether lunch is consumed or not (Stahl et al., 1983), so that it is considered to be a part of a biological rhythm, such as a circadian rhythm (Broughton, 1989).

One of the countermeasures for this post-lunch sleepiness is napping. Afternoon napping is common in many countries and areas (e.g. the siesta) (Webb and Dinges, 1989). However, napping has not only positive effects such as the refreshment of mood and improvements in sleepiness or performance level, but also negative effects such as ‘sleep inertia,’ i.e. impaired alertness usually experienced upon awaking (Lubin et al., 1976; Dinges, 1989, 1992). These positive and negative effects of napping are dependent on the time of day the nap is taken, the duration of the nap, and prior wakefulness before napping (Naitoh, 1981).

Stampi et al. (1990) examined the effects of polyphasic daytime naps after 4 h of night sleep. These nap conditions were 3 (80 min), 5 (50 min) and 12 (20 min) naps per day. The results showed that the 50 min condition napping was least effective because the subjects were awakened from slow-wave sleep (SWS), so that their sleep inertia was increased. The 20 min condition was most effective because the subjects were awakened from lighter sleep stages, so that the sleep inertia was suppressed. The positive effects of short naps (less than 30 min) was also observed after restricted night sleep (Gillberg et al., 1996; Horne and Reyner, 1996; Reyner and Horne, 1997), and during 64 h of continuous work (Naitoh et al., 1992).

* Corresponding author. Tel: +81-824-24-6582; fax: +81-824-24-0759.

PII: S1388-2457(98)00003-0

CLINPH 98005

Dinges (1992) classified naps into 3 types. Replacement naps are taken in response to subjective fatigue, as a consequence of reduced nocturnal sleep. Appetitive naps are taken without regard to fatigue, as a part of an endogenous biphasic sleep cycle. Prophylactic naps are taken in advance of sustained wakefulness. Thus, the short naps studied previously (Stampi et al., 1990; Naitoh et al., 1992; Gillberg et al., 1996; Horne and Reyner, 1996; Reyner and Horne, 1997) can be regarded as replacement naps against restricted night sleep. However, daytime sleepiness does increase in the afternoon even after extended night sleep, e.g. 10 h of time in bed (Carskadon, 1989). The question arises as to whether a short daytime nap has prophylactic effects on daytime sleepiness after a full night's sleep. The present study examined the effects of a 20 min mid-afternoon nap after a full night's sleep on behavioral, subjective and physiological measures.

2. Methods

2.1. Subjects

Seven university students (3 male and 4 female) with good health participated in the study (aged 20–21 years, mean 20.6). Their sleep habits were assessed by the Sleep Habit Inventory (Miyasita, 1994) and Morning-Evening Questionnaire (Horne and Östberg, 1976). They also kept a sleep log for 1 week before the experiment. They all had normal sleep-wake habits, and did not complain of excessive daytime sleepiness or any other sleep-wake problems. They did not show any sign of being irregular sleepers (Taub, 1978). They reported that their retiring and awaking times, and sleep duration varied by less than 2 h over 1 month. Their sleep logs also confirmed this. All 7 subjects were good sleepers (Monroe, 1967); that is, their subjective sleep latencies were less than 10 min, they never awakened during the night, and did not complain of difficulty in falling asleep and remaining asleep. They slept between 6 and 8 h nightly. A recent survey of a Japanese population (Hori et al., 1998) showed that the mean nocturnal sleep time was 6.5 h (SD = 1.0) in college students (age 18–34, mean 18.9, $n = 2684$) and 7.0 h (SD = 1.0) in adults (age 30–85, mean 55.1, $n = 969$). Those results indicated that the present subjects were neither shorter nor longer sleepers (Hartmann et al., 1971). None of the subjects habitually napped or smoked. None was an excessive morning-type or excessive evening-type. All displayed enriched EEG-alpha activity.

2.2. Performance tasks

The following computer tasks were used, as displayed on a personal computer (NEC PC-98VX21). The subjects were instructed to respond as quickly and as accurately as possible.

2.2.1. Logical reasoning

Pairs of characters such as 'AB' or 'BA' were displayed, followed by 8 possible sentences describing the order such as 'A follows B' (Baddeley, 1968). The subjects pressed the 'correct' or 'incorrect' button. Thirty trials were carried out per session.

2.2.2. Addition

Five two-digit numbers were displayed on the computer screen (Willkinson, 1969). The subjects responded by inputing the sum of the numbers using the keyboard. They responded to as many questions as possible within 3 min.

2.2.3. Visual detection

An alphanumeric sequence was displayed for 50 ms at intervals of 2 s (Bakan, 1959). The subject was instructed to press the 'correct' button if 'A' or '3' was presented and to press the 'incorrect' button if not. Eighty trials were presented per session.

2.2.4. Auditory vigilance

Pip tones of 350 ms duration (target) and 500 ms (non-target) were presented randomly at the rate of 1:3 at intervals of 1–3 s (M = 2 s) (Deighton et al., 1972). The subject was instructed to press the 'correct' button when target stimuli were presented, and to press the 'incorrect' button in response to non-target stimuli. Eighty trials were carried out per session.

2.3. Procedure

The subjects participated in the experiment twice with an interval of 1 week, under two conditions (once each). In the Nap condition, the subject took a nap at 14:00 h, and in the No-nap condition, the subject rested without sleeping by sitting on a semi-reclining chair at 14:00 h. For the Nap condition, the subject went to bed at 14:00 h and was awakened by intercom when 20 min had elapsed from the onset of sleep stage 1 (Rechtschaffen and Kales, 1968). If the subject spontaneously awoke from any sleep stage before 20 min had elapsed, he or she remained in bed until a total of 20 min of any sleep stage had accumulated. The order of the Nap/No-nap conditions was counterbalanced across the subjects. Alcoholic intake and excessive exercise were prohibited on the experimental day.

The subjects reported to the laboratory at 22:00 h. They practiced the performance task. The electrodes for EEGs (Fz, Cz, Pz, Oz), horizontal and vertical EOGs, and submentalis EMG were attached and recorded with a polygraph (model 1A97, NEC-Sanei, Tokyo) throughout the study. The subjects slept individually in a sound-proof and air-conditioned isolation unit for 8 h from 00:00 h. They were awakened at 08:00 h. After face washing and breakfast outside the isolation unit, each subject entered the unit again at 10:00 h and stayed alone in it until 18:00 h. Any time cues from 10:00 to 18:00 h were removed.

Twelve evaluation sessions were administered in the period from 10:00 to 14:00 h, and 10 sessions were administered from 14:40 to 18:00 h. Each session was 20 min in length and was comprised of the following 5 elements. (1) EEG recordings: EEG recordings of relaxed wakefulness with both eyes opened and eyes closed were analyzed for 1 min, respectively. (2) Pre-task self-evaluation: subjective sleepiness, fatigue and motivation to the task were evaluated via a 100 mm long visual analog scale (Monk, 1987). Completing this form took approximately 30 s. (3) Computer tasks: the 4 computer tasks described above (logical reasoning, addition, alphanumeric detection and auditory vigilance) were administered for approximately 12 min. The order of the tasks was randomized for each session. (4) Post-task self-evaluation: the subjects estimated their task performance via a visual analog scale. This took approximately 30 s. (5) Five minute break: the subjects could eat a light meal or drink a non-caffeinated beverage. Strenuous exercise, lying in the bed and sleeping were prohibited. For the control of the behavior of the subjects, they were asked to put together as many pieces as possible of a 1500-piece jigsaw puzzle.

2.4. EEG analysis

EEG theta and alpha activities with the eyes open are enhanced with increasing sleepiness (Åkerstedt, 1992). EEG theta activity is often contaminated by eye blinks; therefore, EEG alpha activity in the eyes-open condition was used as the EEG measure in the present study. The power spectra with 0.25 Hz resolution for each session were computed using a fast Fourier transformation by a spectral analyzer (model 7T18A, NEC-Sanei). The 32 s long spectra were obtained by averaging 8 consecutive 4 s epochs. The power spectra were integrated for the alpha (7.5–13.5 Hz) band frequency, and transformed into the magnitude values in microvolts.

2.5. Statistical analysis

The data of the first session, while the subject became accustomed to the new environment, was eliminated from the data analysis because of the stabilization of the physiological and behavioral recordings. To control for individual differences, the time-series data obtained were normalized by subtracting the mean values of the sessions from 10:00 to 13:40 h. To enhance the signal/noise (S/N) ratio, hourly means (3×20 min sessions) were calculated. Then, two-way analyses of variance [2 (Nap or No-nap) $\times$ 7 (time in hours)] with repeated measures were performed for the hourly means of mood (sleepiness, fatigue and motivation to the tasks), performance (reaction time and percent correct of the computer tasks), self-evaluation for each task, and EEG alpha band activity. The degrees of freedom were adjusted by Greenhouse & Geisser's epsilon (Winer et al., 1991). The post-hoc comparisons were performed using the Newman–Keuls method.

3. Results

3.1. Sleep variables

The 1 week sleep logs before each experiment condition showed that the subjects slept for a mean of 441.7 min nightly before the Nap condition, and 436.0 min nightly before the No-nap condition. These values are not significantly different ($t = 2.19$, d.f. = 6, non-significant, n.s.). On the night before the experiment in the laboratory, they slept 467.8 min before the Nap condition, and 443.6 min before the No-nap condition. The at-home and laboratory sleep times were not significantly different (Nap condition: $t = 2.33$, d.f. = 6, n.s.; No-nap condition: $t = 0.35$, d.f. = 6, n.s.). The sleep variables on the pre-experiment night are shown in Table 1. These values were not significantly different between the Nap and No-nap conditions.

However, the total sleep time of one subject in the No-nap condition was shorter (336 min), so that mean sleep time in the No-nap condition was 24.2 min shorter than in the Nap condition. The mean sleep time for the other 6 subjects was 470.3 min (SD = 4.2) in the Nap condition and 461.5 min (SD = 16.0) in the No-nap condition. The difference was 8.8 min, and it was not significantly different ($t = 1.19$, d.f. = 5, n.s.). Then, the results of ANOVAs for these 6 subjects, along with the 7 subjects, were shown in the following analysis.

Table 1
Sleep variables (min) on the pre-experiment night ($n = 7$)

Sleep variables	Nap condition		No-nap condition		t (d.f. = 6)	$P <$
Latency to stage 1	5.9	(4.5)	14.0	(10.3)	1.77	n.s.
Stage 1	12.6	(4.2)	17.7	(14.6)	0.82	n.s.
Stage 2	223.7	(39.5)	201.7	(53.4)	0.81	n.s.
Stage 3	63.6	(24.8)	63.4	(18.3)	0.02	n.s.
Stage 4	64.3	(32.3)	71.1	(49.4)	0.28	n.s.
Stage 3 + 4	127.9	(54.1)	134.5	(62.2)	0.20	n.s.
Stage REM	103.6	(18.3)	89.7	(19.9)	1.26	n.s.
Total sleep time	467.8	(8.6)	443.6	(46.1)	1.26	n.s.

Standard deviations are given in parentheses; n.s., non-significant.

Table 2

Sleep variables (min) during a 20 min nap for each subject

Sleep variables	Subject no.							Mean	SD
	1	2	3	4	5	6	7		
Latency to stage 1	7	7	3	9	7	4	10	6.7	2.5
Stage 1	9	4	2	8	8	4	8	6.1	2.7
Stage 2	6	16	7	11	12	6	11	9.9	3.7
Stage 3 + 4	–	–	–	–	–	–	–	–	–
Stage REM	6	–	11	–	–	10	–	3.9	5.0
Total sleep time	21	20	20	19	20	20	19	19.9	0.7
Sleep stage at wakening	2	2	2	2	2	2	2	–	–

The sleep variables of the nap are shown in Table 2. The subjects slept 20 min during the mid-afternoon nap. All subjects were in sleep stage 2 when awakened. SWS did not occur for any subjects, while rapid eye movement (REM) sleep occurred in 3 subjects. These REM episodes were considered to be sleep-onset REM periods (SOREMPs).

3.2. Mood

Fig. 1 shows the hourly means of the self-ratings of sleepiness, fatigue and motivation to the tasks for the Nap and No-nap conditions. Sleepiness declined after napping. The main effect of the Nap was marginally significant ($F(1, 6) = 5.20$, $\epsilon = 1.0$, $P < 0.10$ for 7 subjects; $F(1, 5) = 4.85$, $\epsilon = 1.0$, $P < 0.10$ for 6 subjects). The post-hoc comparisons showed that sleepiness significantly decreased at 16:00 h in the Nap condition compared with the No-nap condition

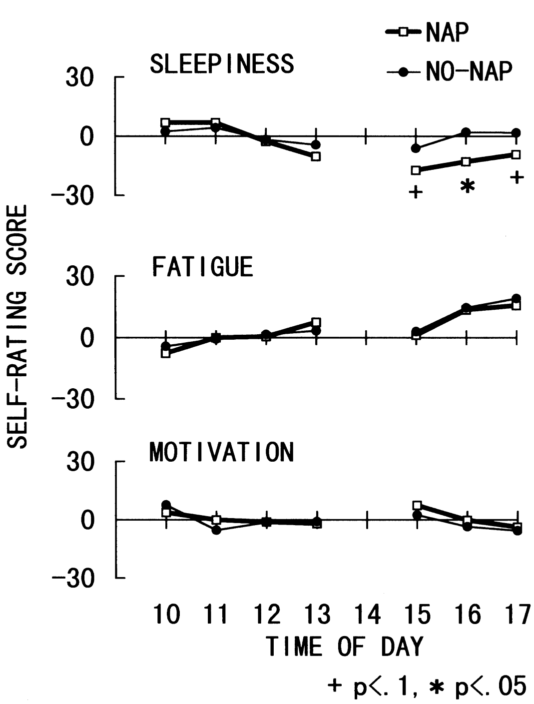

Fig. 1. Hourly means of self-ratings for sleepiness, fatigue, and motivation to the tasks for 7 subjects. Data were normalized by subtracting the mean values of the 20 min sessions from 10:00 to 13:40 h.

($P < 0.05$). At 15:00 and 17:00 h, the differences between the conditions were marginally significant ($P < 0.10$). Fatigue steadily increased as a function of time. The main effect of time was significant ($F(6, 36) = 6.54$, $\epsilon = 0.39$, $P < 0.01$ for 7 subjects; $F(6, 30) = 6.89$, $\epsilon = 0.34$, $P < 0.02$ for 6 subjects). Neither the main effect nor the interaction were significant for motivation to the tasks.

3.3. Performance

Neither the main effect nor interaction was significant for the reaction times of all computer tasks.

Fig. 2 shows the time fluctuations of the percentage correct of these tasks. For the logical reasoning task, the main effect of the Nap was significant ($F(1, 6) = 7.70$, $\epsilon = 1.0$, $P < 0.05$ for 7 subjects; $F(1, 5) = 4.98$, $\epsilon = 1.0$, $P < 0.08$ for 6 subjects). The post-hoc comparison showed that the percentage correct of the logical reasoning task was marginally increased at 15:00 h when the subjects had napped ($P < 0.10$). The main effect of time was significant for the percentage correct of the calculation task ($F(6, 36) = 3.36$, $\epsilon = 0.55$, $P < 0.05$ for 7 subjects; $F(6, 30) = 2.88$, $\epsilon = 0.41$, $P < 0.10$ for 6 subjects). This task significantly improved at 15:00 h when the subjects had napped ($P < 0.05$). Neither the main effect nor the interaction were significant for the visual detection task. The main effect of the Nap was marginally significant for the auditory vigilance task ($F(1, 6) = 3.96$, $\epsilon = 1.0$, $P < 0.10$ for 7 subjects; $F(1, 5) = 4.03$, $\epsilon = 1.0$, $P < 0.10$ for 6 subjects). The percentage correct of this task significantly improved after napping from 15:00 to 17:00 h ($P < 0.05$).

Fig. 3 shows the results of the self-rating scores for the task performances. The self-rated performance levels hardly changed throughout the experiment in the No-nap condition. However, these scores improved when the subjects napped. The main effect of time was significant for the logical reasoning ($F(6, 36) = 4.58$, $\epsilon = 0.56$, $P < 0.02$ for 7 subjects; $F(6, 30) = 4.25$, $\epsilon = 0.46$, $P < 0.05$ for 6 subjects), calculation ($F(6, 36) = 3.38$, $\epsilon = 0.47$, $P < 0.05$ for 7 subjects; $F(6, 30) = 3.32$, $\epsilon = 0.45$, $P < 0.06$ for 6 subjects), and auditory vigilance tasks ($F(6, 36) = 3.38$, $\epsilon = 0.43$, $P < 0.05$ for 7 subjects; $F(6, 30) = 2.60$, $\epsilon = 0.47$, $P < 0.10$ for 6 subjects). The post-hoc comparison showed

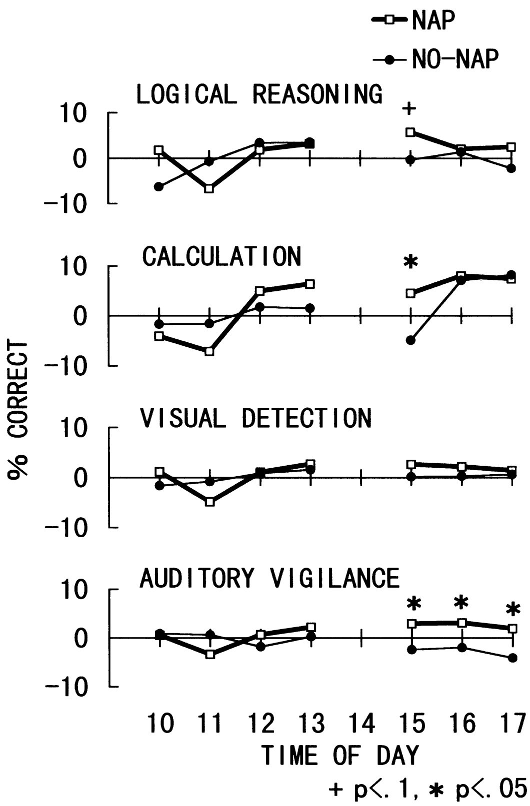

Fig. 2. Hourly means of percentage correct values for the logical reasoning, calculation, visual detection and auditory vigilance tasks for 7 subjects. Data were normalized by subtracting the mean values of 20 min sessions from 10:00 to 13:40 h.

that the self-rating scores for logical reasoning significantly improved at 15:00 h ($P < 0.05$) and marginally at 16:00 h ($P < 0.10$) when the subjects napped. The scores were significantly enhanced for calculation at 15:00 h ($P < 0.05$), and marginally increased at 15:00 h ($P < 0.10$), and significantly increased at 16:00 h for auditory vigilance. Neither the main effects nor interaction were significant for the visual detection task.

3.4. EEG alpha activity

Due to a technical error, the EEG data of Cz area in the Nap condition for one subject (the same subject who slept less on the pre-experimental night in the No-nap condition) could not be used for the analysis. Thus, the numbers of subjects used for the following analysis were 6 for the Cz area, and 7 for the Fz, Pz and Oz areas.

The amplitude of the eyes-open EEG alpha activity increased in the No-nap condition (Fig. 4), and was suppressed when the subjects napped. The main effect of time was significant for all EEG locations (Fz: $F(6, 36) = 6.04$, $\epsilon = 0.53$, $P < 0.01$ for 7 subjects, $F(6, 30) = 5.76$, $\epsilon = 0.46$, $P < 0.01$ for 6 subjects; Cz: $F(6, 30) = 6.25$, $\epsilon = 0.51$, $P < 0.01$ for 6 subjects; Pz: $F(6, 36) = 6.56$, $\epsilon = 0.45$, $P < 0.01$ for 7 subjects, $F(6, 30) = 5.74$, $\epsilon = 0.39$, $P < 0.02$ for 6 subjects; Oz: $F(6, 36) = 3.89$, $\epsilon = 0.34$, $P < 0.05$ for 7 subjects, $F(6, 30) = 3.10$, $\epsilon = 0.31$, $P < 0.10$ for 6 subjects). A significant main effect of the Nap was observed for the frontal-central areas (Fz: $F(1, 6) = 27.32$, $\epsilon = 1.0$, $P < 0.01$ for 7 subjects, $F(1, 5) = 31.12$, $\epsilon = 1.0$, $P < 0.01$ for 6 subjects; Cz: $F(1, 5) = 12.73$, $\epsilon = 1.0$, $P < 0.02$ for 6 subjects), and a significant Nap by time interaction was observed for the frontal area ($F(6, 36) = 3.51$, $\epsilon = 0.53$, $P < 0.05$ for 7 subjects, $F(6, 30) = 3.08$, $\epsilon = 0.46$, $P < 0.07$ for 6 subjects). The post-hoc comparison showed that the EEG alpha activity at the frontal-central area was significantly suppressed from 15:00 to 17:00 h after napping. It was significantly suppressed at 16:00 h in the parietal area.

4. Discussion

The present results revealed the positive effects of a 20 min mid-afternoon nap on subjective, behavioral and physiological measures. Sleepiness, the performance of auditory vigilance and EEG alpha activity at the frontal-central area were improved for 3 h after napping. Thus, the 20 min nap during the post-lunch dip had positive effects on the maintenance of the subsequent vigilance level. It also

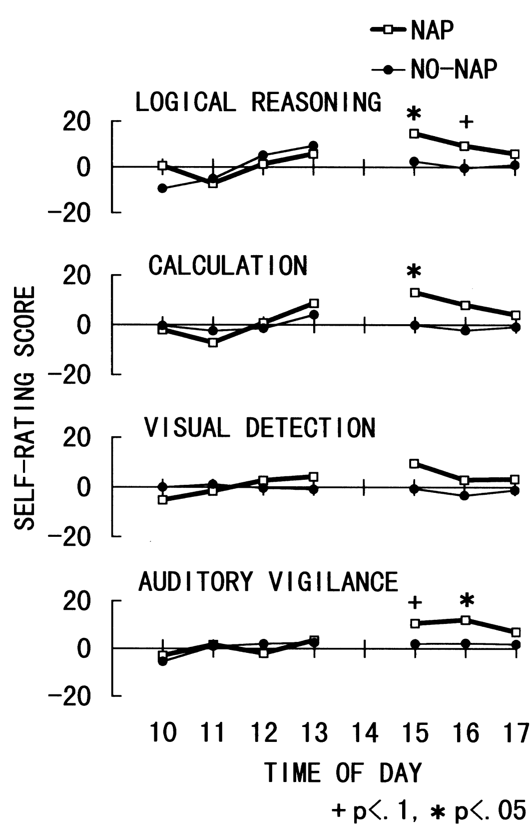

Fig. 3. Hourly means of self-ratings for the performance level of logical reasoning, calculation, visual detection and auditory vigilance task for 7 subjects. Data were normalized by subtracting the mean values of 20 min sessions from 10:00 to 13:40 h.

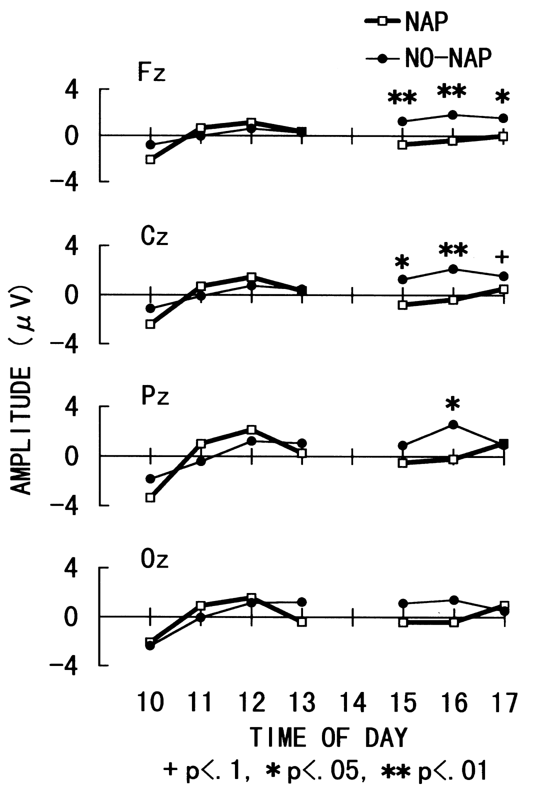

Fig. 4. Hourly means of EEG alpha band activities with eyes-open from frontal (Fz), central (Cz), parietal (Pz) and occipital (Oz) scalp locations on the midline for 7 subjects. Data were normalized by subtracting the mean values of 20 min sessions from 10:00 to 13:40 h.

improved the performance of the higher cognition demand tasks of logical reasoning and calculation, for 1 h. The self-rating scores for the performance tasks were improved for 1–2 h after napping, suggesting that the 20 min nap enhanced the subjects' self-confidence regarding their task performance. Although some measures (fatigue, motivation, reaction time) did not differ between the Nap and No-nap conditions, no negative effects of napping were observed. Thus, the present results support the previous studies which showed the restorative effects of short (less than 30 min) daytime nap(s) (Stampi et al., 1990; Naitoh et al., 1992; Gillberg et al., 1996; Horne and Reyner, 1996; Reyner and Horne, 1997).

The question of which factors are related to the restorative power of a nap remains. Lumley et al. (1986) suggested that the amount of SWS and the continuity of sleep were the most important for the alerting effect of napping. The importance of the amount of SWS in particular was supported by the previous findings that more than an 1 h afternoon nap improved sleepiness and performance after total sleep deprivation (Lumley et al., 1986; Lavie and Weler, 1989), or prolonged continuous work (Naitoh et al., 1982; Dinges et al., 1987). The short (less than 30 min) naps during continuous work (Naitoh et al., 1992) and after restricted night sleep (Gillberg et al., 1996), which showed positive effects on the performance level, also contained SWS.

However, a study of polyphasic short daytime nap conditions by Stampi et al. (1990) showed that the shortest (20 min) nap condition, which was virtually without SWS (only 4%), was the most effective for performance in comparison with longer (50 and 80 min) naps. SWS occurred in the 50 and 80 min conditions, but these conditions induced sleep inertia, so that performance declined. In the present study, SWS did not occur during the nap, suggesting that the restorative power of a short nap after normal night sleep is not always dependent on the amount of SWS. The previous studies were performed with subjects under a sleep 'debt,' so that SWS would be required to restore the vigilance level. For example, Lumley et al. (1986) observed that a 15 min morning nap after one night of sleep deprivation had little alerting effect, and that the amount of SWS was only 2.9 min.

Furthermore, the occurrence of SWS during a daytime nap may induce a decrease of SWS in the subsequent night sleep (Karacan et al., 1970; Feinberg et al., 1992), so that sleeplessness during the night would occur. SWS during a short (less than 30 min) daytime nap after normal night sleep might be rather harmful.

Thus, the continuity of sleep (Bonnet, 1986; Lumley et al., 1986; Magee et al., 1987) might be most important. Studies which examined the effects of sleep disruption (Bonnet, 1986; Magee et al., 1987) showed that a minimum of 4–10 min of undisrupted sleep is required for restorative power. Helmus et al. (1997) reported that a longer (2 h) rather than shorter (15 min) daytime nap was more effective. In the present study, the subjects slept a total amount of 20 min during the nap after 7–8 h of prior night sleep, whereas the sleep efficiencies of the nap used by Helmus were lowered; 73.6% of 15 min (total nap time was 11.0 min) after one-night sleep deprivation and 38.0% (total nap time was 5.7 min) after 8 h of night sleep. Thus, the shorter (15 min) nap studied by Helmus might be too short to restore the vigilance level. The age of the subjects may also be related to the results. The subjects were middle-aged (mean 40.8 years) in Helmus's study, whereas university students (mean age 20.6 years) were examined in the present study. The age effect should be further explored.

The present nap was composed mainly of stage 2 sleep. REM sleep occurred for 3 subjects, whereas it did not for the other 4 subjects. Daytime sleepiness increases when prior night sleep is restricted, and it decreases when prior night sleep is extended (Carskadon and Dement, 1982). The last half of normal night sleep is composed mainly of stage 2 and REM sleep, so that restricted or extended night sleep causes an increase or decrease in the amount of stage 2 and REM sleep. This suggests that the amount of stage 2 and REM sleep would also contribute to daytime sleepiness. However, the duration of REM sleep depends on circadian temperature cycles (Czeisler et al., 1980), so that stage 2 sleep may be more important in this regard. Spiegel (1981) observed that subjective sleep quality was negatively related to the duration of stage 1 sleep and wake time in the night in elderly men, whereas it was positively related to the duration of stage 2 and REM sleep in elderly women. He also noted that 'in young subjects, the sensation of restful sleep may be positively related to the duration of stage 2'. These findings may indicate that a fixed amount of stage 2 sleep in a daytime short nap would be required for restoring the daytime vigilance level.

The abruptness of awakening from a nap is also an important factor (Dinges, 1989; Dinges, 1992). In the present study, all subjects awakened from sleep stage 2, so that the effects of sleep inertia were slight. Rather, cognitive functions such as logical reasoning or calculation were enhanced, and self-evaluation improved just after napping.

Daiss et al. (1986) observed that after 7–8 h of night sleep, 1 h of bed-rest without sleep improved mood, as did a 1 h daytime nap. Horne and Reyner (1996) also reported that subjects who could not sleep during the nap period reported an improvement of mood. The bed-rest effect cannot be denied in the present results.

It should also be noted that the present subjects were university students. It is well-known that the sleeping habits of individuals at this age are apt to be irregular and shortened. The present subjects, however, had regular sleep–wake habits, and their nocturnal sleep times were not shorter in comparison with the Japanese adults. On the contrary, the latency to sleep stage 1 of the daytime nap was too short (mean 6.7 min). The subjects whose mean sleep latencies on multiple sleep latency test (MSLT) were less than 6 min may be classified as 'sleepy' individuals (Roehrs et al., 1990). Roehrs et al. (1990) observed that 'sleepy' normals had shorter nocturnal sleep latencies and higher sleep efficiencies when compared to 'alert' normals whose mean MSLT scores were more than 16 min. Their results suggested the possibility that 'sleepy' subjects had chronic sleep debts. SOREMPs occurred in 3 of the 7 subjects in the present study. These subjects were not diagnosed as having narcolepsy, because they did not have daily daytime sleep episodes and did not show cataplexy. It was reported that SOREMPs occurred in the MSLT of normal subjects (Bishop et al., 1996). These individuals were sleepier than those without SOREMPs (their mean MSLT scores were 6.2 min versus 10.8 min). The present results were essentially the same. The latencies to sleep stage 1 during the nap were shorter for those who showed SOREMPs (3, 4 and 7 min) than in those without SOREMPs (7–10 min). These results suggested that the present subjects might be chronically sleep deprived. The effects of a short daytime nap for 'alert' individuals should be further studied.

In conclusion, the present 20 min nap had positive effects on the subsequent vigilance level, and the nap was terminated in sleep stage 2, so that the negative effect on sleep inertia was negligible. In addition, the nap was too short to contain SWS, so that the negative effect on subsequent night sleep would be expected to be slight. Thus, a 20 min nap in the mid-afternoon can be very useful as a countermeasure to post-lunch sleepiness.

Acknowledgements

This study was supported in part by the Special Coordination Funds for Promoting Science and Technology from the Science and Technology Agency of Japan, and by a Grant-in-Aid for Scientific Research funded by the Japanese Ministry of Education, Science, Sports and Culture (No. 08710047).

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